Preparing the next generation of health professionals to tackle climate change: Are China's medical students ready?

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ABSTRACT

Background: Climate change is the biggest global health threat of the 21st century. Medical students will lead the health sector responses and adaptation efforts in the near future, yet little is known in China about their knowledge, perceptions and preparedness to meet these challenges.
Methods: A nationwide study was conducted at five medical universities across different regions of China using a two-stage stratified cluster sampling design. A self-administered questionnaire was applied to collect the information including perception, preparedness and educational needs in response to climate change. The data were first analyzed descriptively, then chi-square tests and kruskal wallis tests were applied to determined differences among subgroups, and logistic regression analysis were deployed to detect the socio-demographic factors influencing student's perception.
Results: A total of 1436 medical students were approached and 1387 participated in the study (96.6% response rate). Most students were aware of the health impacts because of climate change, with over 90% perceived air quality-related and heat-related illness, while only a small part identified undernutrition and mental health. Approximately 90% embraced their role in tackling climate change, but 50% reported themselves and the health sectors were not adequately prepared. Compared to clinical students, preventive medicine students were more likely to perceive their responsibility to address climate change (OR:1.36, 95% CI: 1.04, 1.78). Also, 80% students admitted insufficient information and knowledge on climate change and health. Most students agreed that climate change and its health impacts should be included into their current curriculum.
Conclusions: Medical students in China were aware of climate change and felt responsible, but were not ready to make responses to its health impacts. Educational efforts should reinforce eco-medical literacy development and capacity building in the era of climate change.

1. Introduction

Climate change is now regarded as a biggest global health problem requiring health sector preparedness (Smith et al., 2014; Watts et al., 2015). Its effects are already being observed in China and future projections represent an unacceptably high and potentially catastrophic risk to human health (Zing et al., 2008). Climate change affects human health through a wide range of hazardous exposures, including extreme weather events, altered air quality, shifting patterns of infectious disease, as well as sea level rise, ocean acidification, conflict and migration (McMichael et al., 2012). Given the inertia of the climate system, an increase in hazardous exposures associated with climate change is unavoidable (Haines et al., 2014), though ultimately health impacts will depend substantially on the degree of effective adaptation. Notably, the impacts of climate change will be concentrated in poorer and vulnerable populations, where climate-sensitive diseases are common, exacerbating existing health inequalities, and stressing the health sector further in these regions (WHO, 2008).

Health professionals have a clear duty and obligation to lead the efforts to protect health from climate change (Friedrich, 2017; Gill, 2008; Watts et al., 2015). Similar to leadership in response to other emerging threats, health professionals confronting climate change can

highlight the inter-connectedness of climate change and health, advocate environmentally sustainable approaches to health services, promote health benefits of mitigation policies, provide healthcare for affected populations, facilitate the building of community resilience, monitor emerging hazards and conduct research to appraise evidence to support adaptation (Gill et al., 2007; Gill and Stott, 2009; Green et al., 2009; McMichael et al., 2008; Weaver et al., 2010).

While health professionals are vital to the climate actions, previous studies have found that the health community is ill-prepared to detect, prevent or ameliorate climate-related health problems and craft planned adaptations (Maibach et al., 2008). Most importantly, the health sector in many countries has not yet made climate change preparedness a priority.

To cope with the health impacts of climate change, engaging medical students is a critical initiative. In China, population health activities are managed by health professionals who have received clinical medicine, preventive medicine or nursing training. The current generation of medical students will practice from the 2020 s to the 2060 s, a time of emergence for climate change related health impacts. Their efficiency in coping with this biggest challenge of the century may depend on the expertise and skills acquired from their present educational training. Therefore, understanding current medical students' perception and capacity in response to climate change is of great significant in educational planning. Yet, to date there is little literature to rely on and there is no research in China for appropriate educational innovations. This study aims to answer three questions: First, to what extent do Chinese medical students perceive climate change and its health impacts? Second, how do the medical students perceive their roles in coping with climate change? And third, what are the information, education and training needs identified by the medical students?

2. Methods

2.1. Data collection

We conducted an anonymous written survey among a sample of Chinese medical students from five universities with medical colleges. A sampling frame was designed to capture data from all regions of the country and a two-stage stratified cluster sampling design was applied in this study. Firstly, we divided mainland China into five parts including north, west, south, east, and central part with the consideration of geographic and climatic variation, and with one top medical university purposively selected in each part. The selected universities are Harbin Medical University in Harbin, Sichuan University in Chengdu, Sun Yat-sen University in Guangzhou, Fujian Medical University in Fuzhou and Huazhong University of Science and Technology in Wuhan. Secondly, in each selected university, we used cluster sampling and randomly selected around 250 medical students (clinical medicine, preventive medicine or nursing students) from third or fourth grade by taking the whole class as a unit.

This study was approved by the medical ethics committee of School of Public Health, Sun Yat-sen University. Written informed consent was obtained from study participants. From March to May 2017, the study participants were gathered in a classroom by taking a class as a unit, and it took about 10–15 min for them to complete the self-administered questionnaire. The integrity of the return questionnaire was checked by our investigators in the field. This study was a one-time survey and there was no follow-up.

2.2. Survey instrument

A draft questionnaire was developed based on existing literature (Bedsworth, 2009; Maibach et al., 2008, 2015; Polivka et al., 2012; Roser-Renouf et al., 2016). We then conducted a focus group discussion with 6 non-selected students and administered a draft survey to 30 non-selected students to improve its content validity and to calculate the

sample size.

The final version of the questionnaire comprised 33 questions in four parts. The first part of the questionnaire asked questions about perceptions of climate change and its health impacts. Four main questions assessed general perceptions and knowledge regarding climate change and health. Next, to compare the difference between unprompted and prompted responses, two open-ended questions and two lists of closed-ended questions about the specific health issues and vulnerable populations were presented. Then, three questions were presented to assess the students' perceptions of the magnitude of climatic health threats. For close-ended questions in this part, a score of one point was given each time a student identified a health impact or identified a vulnerable group. We accumulated the sum scores of each student and performed kruskal wallis tests for original scores to detect the difference between sub-groups. After that, we took the mean score as the cut-off point to categorize their perceptions on health impacts and on vulnerable groups into high or low groups, respectively. The second part of the questionnaire was composed of six questions on the responsibilities, abilities, and preparedness of medical students or the health sector to address health-related impacts. These questions used a Likert scale, with a range of –3 (strongly disagree) to 3 (strongly agree) as response options, with no neutral midpoint. For questions in this part, a score of one point was given each time a student expresses positive attitude (including "mildly agree", "somewhat agree" and "strongly agree"). We did subgroup analysis using kruskal wallis tests and then categorized their perceptions on responsibilities and abilities into high or low groups with same approach above. The third part of the questionnaire asked ten questions on information, education, and training needs for helping the health sector address climate change and its health impacts. And the last part collected demographic information of respondents, including gender, major, location of hometown, per capital income of family and self-rated health status. According to National Bureau of Statistics of China, we divided hometown location of surveyed students into east, central, west and northeast region by taking geographic, climatic conditions and socioeconomic development status into consideration (National Bureau of Statistics of China, 2011)

2.3. Statistical analyses

Data of valid questionnaire (missing value less than 3) were double-entered using Epidata 3.1 and then imported into STATA statistical software (version 14.0, STATA Corp) for analysis. First, responses were analyzed descriptively. Second, chi-square tests or kruskal wallis tests were applied to determine differences among participant subgroups. Third, several unconditional logistic regression models were deployed to detect the potential influence factors of medical students' perceptions on health impacts, on vulnerable groups and on their responsibilities and abilities (0 = low perception, 1 = high perception). All statistical analyses we applied were two-sided and we considered p-values < 0.05 as statistically significant. Missing data (accounting < 0.5%) were not involved in the analysis.

3. Results

A total of 1436 students were approached and 1387 valid questionnaires were collected in the study (response rate, 96.6%). Approximately a quintile of the participants (n = 260) belonged to each surveyed university. Most participants were female, with per capital income of family ranging from US$ 300–749 monthly. The average age of students was 21.8 years old (ranging from 17 to 28). Most students (83.8%) assessed their own health status as good or beyond (Table 1).

3.1. Perceptions of climate change and its health impacts

In this study, 68% of students agreed that the process of climate change is controllable through effective mitigation and adaptation.

Table 1
Summary statistics of participant information.

Characteristic	N	Percentage (%)
Total	1387	100.0
Gender		
Male	461	33.2
Female	926	66.8
University		
Sun Yat-sen University	331	22.4
Huazhong University of Science and Technology	248	17.9
Sichuan University	262	18.9
Fujian Medical University	258	18.6
Harbin Medical University	308	22.2
Major		
Clinical medicine	644	46.4
Preventive medicine	430	31.0
Nursing	313	22.6
Location of hometown		
Central China	304	22.1
Eastern China	506	36.8
Western China	219	15.9
Northeastern China	345	25.1
Per capital income of family		
< $150	154	11.1
$150–299	284	20.5
$300–749	514	37.1
$750–1499	293	21.1
≥ $1500	127	9.2
Self-rated health status		
Very good	303	21.9
Good	858	61.9
Medium	208	15.0
Poor	18	1.3

Preventive medicine students were more likely to believe climate change is controllable than clinical medicine and nursing students (see Supplemental material, Table S1).

When asked whether climate change and its health impacts would overall have net beneficial or detrimental effects, the majority of students stated that climate change and its health-related impacts are detrimental, with 17.4% identifying climate change as "very bad" and 13.4% identifying the health impacts of climate change as "very bad" (Fig. 1). Females were significantly more likely than males to identify climate change and its health-related impacts as a "bad" thing (χ^2 = 32.87, p < 0.01, and χ^2 = 26.02, p < 0.01, respectively). Clinical medicine and preventive medicine students were more likely than nursing students to agree health impacts of climate change are bad (χ^2 = 20.71, p = 0.02) (see Supplemental material, Table S2).

The average accuracy of all 4 questions about the causes of climate change (true or false) was 57.8% and the worst knowledge was about global CO_2 concentrations in the atmosphere; only 15.7% students

Fig. 1. Medical students' perceptions about climate change and its health impacts in general.

knew about the changes in atmospheric CO_2 concentrations during the past centuries [see Supplemental material, Table S3]. Only 8.1% of medical students correctly answered all questions. Nursing student had lower accuracy than clinical medicine and preventive medicine students (χ^2 = 11.32, p < 0.01) (see Supplemental material, Table S4).

In the responses of closed-ended questions about the health impacts and vulnerable groups, over 90% students agreed air quality-related illness, heat-related illness, and disruption of health care services during extreme weather events as expected climate change related health impacts, while fewer identified undernutrition (38.9%) and mental health conditions (63.7%). People who are sick or disabled, seniors, infants or young children, and people living in specific geographic locations were most commonly identified as vulnerable groups. A lower proportion (73%) of respondents identified people with low socioeconomic status as vulnerable (see Supplemental material, Table S5).

The response rates to the two open-ended questions were both above 85%. The open-ended responses showed some similarities with the closed-ended responses: air quality-related and heat-related illness were the most recognized health impacts of climate change, the vulnerability of seniors, infants or young children, outdoor workers and farmers, people who are sick or disabled and people living in specific geographic locations were also identified by medical students. However, discrepancies were also apparent. Water-borne infectious disease was rarely mentioned on the open-ended responses but identified by over 80% students in the close-ended question. Respondents ranked vector-borne infectious disease more highly on the open-ended questions than on the closed-ended questions. (Fig. 2).

Discrepancies of students' perception on health impacts and vulnerable groups existed between different majors (χ^2 = 12.07, p < 0.01, and χ^2 = 9.23, p < 0.01, respectively) (see Supplemental material, Table S6). And results of logistic regression showed that, compared to clinical medicine students, preventive medicine students demonstrated lower awareness of health impacts (OR: 0.71, 95% CI: 0.54, 0.92) and nursing students demonstrated lower awareness of health impacts (OR: 0.69, 95% CI: 0.51, 0.94) and vulnerable groups (OR: 0.59, 95% CI: 0.44, 0.81) (Table 3).

The majority of students agreed that the climate change health impacts will be serious in the next 20 years, with one third strongly agreeing that the impacts will be serious in China (35.9%) and around the world (39.1%), while a significantly lower percentage (24.6%) noted that it would be serious in their own communities. And preventive medical students were less likely to approve climate change is a local concern (χ^2 = 22.24, p < 0.01) (see Supplemental material, Table S7). There were also regional differences in this aspect. Students whose hometown located in the western and eastern China were more likely than those lived in northeastern or central regions to agree that the health impacts would be serious in their communities (χ^2 = 11.10, p = 0.01). (data not shown).

3.2. Perceptions of responsibility and ability

Although approximately 90% respondents perceived addressing the health-related impacts of climate change as their responsibility, and believed their expertise and skills can play an important role in doing so, only 50% felt that their expertise and skills are adequate. Similarly, 89.7% medical students agreed that their respective health sector should be concerned about preventing health problems due to climate change, and around 80% believed their sectors' actions would reduce the adverse effects of climate change, yet only 50% believed that health sectors are well-prepared to address climate change related health impacts (Table 2). Differences of perception on responsibility and ability across the majors was significant (χ^2 = 18.01, p < 0.01) (see Supplemental material, Table S6). Preventive medicine students had higher perception on their responsibility and ability than clinical medicine students (OR:1.36, 95% CI: 1.04, 1.78). (Table 3).
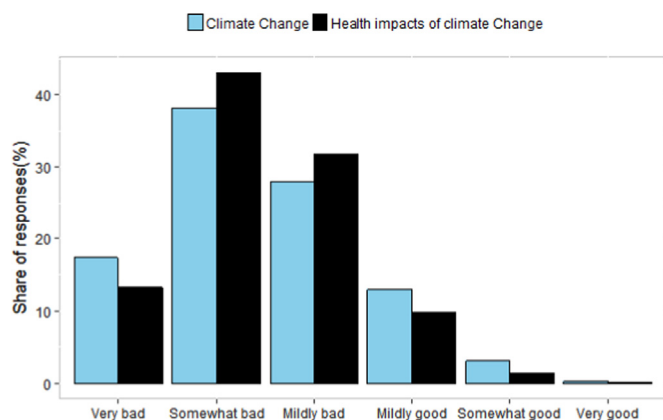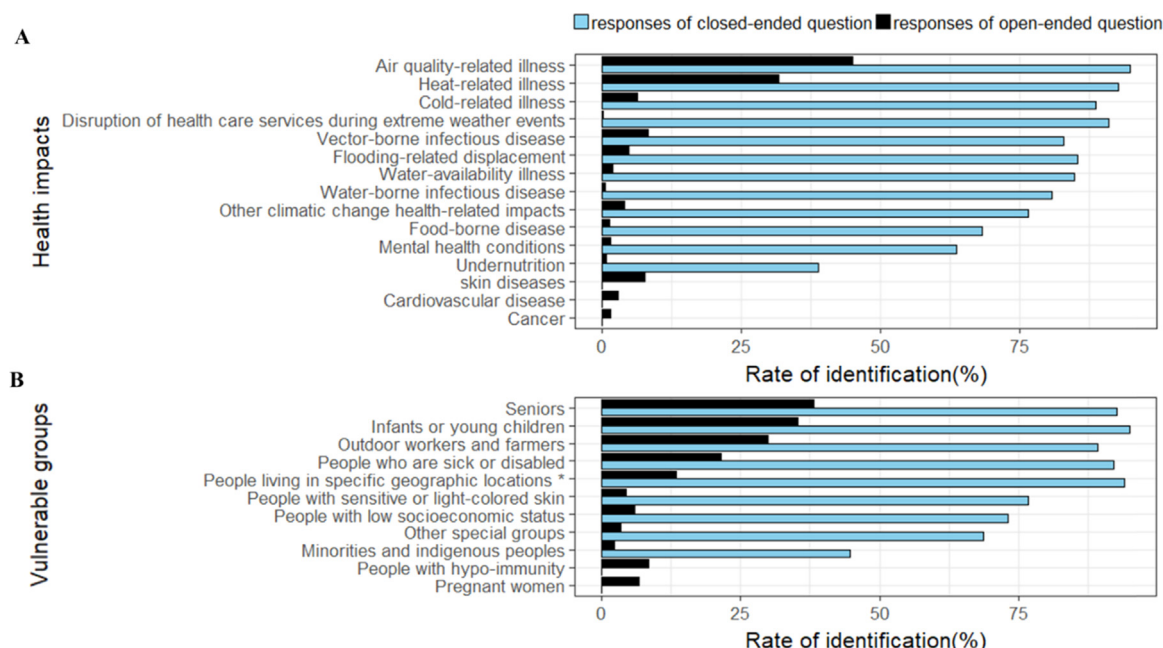
Fig. 2. Similarity and discrepancy between open- and closed-ended responses to questions on health-related impacts (A) and vulnerable groups (B) of climate change. *: residents of cities, coastal, storm prone and flood regions, and other specific regions.

3.3. Education and training needs

The majority of students thought that they had neither adequate information to respond to current public health emergencies (86%) nor to the potential health risks associated with climate change (87.2%) (data not shown). The most popular information source was the internet (94.5%), followed by electronic mass media (70%) and university teachers (50%). Regarding the authority information sources, Departments of Public Health, Environment Protection Agencies, and Bureaus of Meteorology were most trusted by medical students. Compared to clinical medicine and nursing students, more preventive medicine students identified university teachers as their climate change related information sources ($\chi^2 = 16.9$, p < 0.01), and more trusted Departments of Public Health ($\chi^2 = 19.5$, p < 0.01). Most respondents (83.1%) reported that staff expertise in climate science is an important resource, followed by technical/analytical skills to assess health impacts (79.7%). (Table 4). The majority of respondents indicated the need for additional information regarding climate change attributable health risks, and population health/disease tracking database was rated as the most helpful resource (70%). (see Supplemental material, Table S8).

79.8% medical students claimed that they did not have the necessary knowledge to address the health-related impacts of climate change. Among these students, 35.8% cited the lack of complete theoretical framework and teachers' guidance as a reason, followed by inadequate training (33.4%), and lack of social and professional attention (19.3%) (data not shown).

The majority of respondents (especially among preventive medicine students) thought that climate change should be integrated into medical education and training systems. Climate change-related clinical knowledge and skills (71.0%), knowledge of population health (61.6%) and emergency care (59.4%) were identified as the most important competencies for climate change. Integrating climate change into the medical education curriculum was preferred (32.2%) as the mode for education and training within the current system, while more preventive medicine students (42.6%) preferred specific practical training. (Table 5).

4. Discussion

As the first nationwide cross-sectional study of climate change and health among medical students in China, this survey helps clarify the level of awareness and the extent of knowledge deficits among the future health workforce in China who will be faced to climate change. Overall, medical students were aware of the health threats posed by climate change and also recognized their responsibility to respond the problem. At the same time, a striking 50% reported that themselves and the health sector were not well-prepared to tackle climate change related health threats. Integration of climate change into the existing medical education curriculum would ameliorate information insufficiency and facilitate climate change preparedness.

4.1. Knowledge and perceptions

Most medical students in China were aware of the threats of climate change and its health impacts. This was consistent with findings from previous studies conducted in public health officers in California (Bedsworth, 2009), American public health nurses (Polivka et al., 2012), African American physicians (Sarfaty et al., 2014), and health science students in Ethiopia (Nigatu et al., 2014). This high awareness can be served as a good start point for preparing and engaging medical students to tackle climate change.

Female students had a marginally better understanding of the harmfulness of climate change than the males, similar to studies in Ethiopia (Nigatu et al., 2014) and Malaysia (Rahman et al., 2014). The explanation may be that females hold more scientifically accurate beliefs about climate change than males do (McCright, 2010); it may also be that social concerns like the impact of climate change and health are somewhat gendered via socialization and other norms.

Despite widespread concern and relatively high awareness, important misunderstandings were evident that climate change is perceived by some of medical students as a distant threat with limited personal relevance. Previous surveys to public health nurses (Polivka et al., 2012) and environmental health directors (Syal et al., 2011) also showed that, compared to the United States and around the world, fewer health professionals believed the impacts would be greater in their jurisdiction. Since climate change impacts exhibit large

Table 2
Medical students' perceptions on their responsibility and ability to address climate change health-related impacts.

	Disagree				Agree				χ^2	p-value
	Total n (%)	Strongly disagree n (%)	Somewhat disagree n (%)	Mildly disagree n (%)	Total n (%)	Mildly agree n (%)	Somewhat agree n (%)	Strongly agree n (%)		
In addressing climate change health-related impacts, medical students themselves......										
Have a responsibility	164 (11.8)	60 (4.3)	59 (4.3)	45 (3.2)	1223 (88.2)	204 (14.7)	473 (34.1)	546 (39.4)		
Can play an important role	154 (11.1)	36 (2.6)	63 (4.5)	56 (4.0)	1232 (88.9)	238 (17.2)	489 (35.3)	505 (36.4)	1116.4	< 0.01
Have enough expertise and skills	692 (49.9)	129 (9.3)	237 (17.1)	326 (23.5)	695 (50.2)	357 (25.8)	292 (21.1)	46 (3.3)		
In addressing climate change health-related impacts, the health sectors......										
Should concern about the prevention	143 (10.3)	29 (2.1)	53 (3.8)	61 (4.4)	1243 (89.7)	227 (16.4)	398 (28.7)	618 (44.6)		
Can take effective actions	297 (21.5)	40 (2.9)	109 (7.9)	148 (10.7)	1090 (78.7)	389 (28.1)	456 (32.9)	245 (17.7)	1005.2	< 0.01
Are well-prepared	683 (49.3)	118 (8.5)	249 (18.0)	316 (22.8)	703 (50.7)	355 (25.6)	275 (19.8)	73 (5.3)		

geographic variations, local conditions must be taken into consideration while tackling climate change. This kind of underestimation toward local threats could limit their motivation linking climate change with locally observed health effects. Incorporating downscaled, locally relevant projections of climate change and the ranges of likely health effects might be a useful approach to this concern.

Respondents who lived in the west and east regions of China were more likely than other regions to believe that climate change is a local community concern. These differences may stem from personal experiences caused by different levels of exposures, as well as unmeasured social, cultural, or economic factors. Several studies suggest that personal experience is a significant determinant of people's awareness of climate change (Akerlof et al., 2013; Bloodhart et al., 2015; Broomell et al., 2015). Limited socioeconomic development in the western region might cause limited adaptation, and the eastern region is exposed to more heat extreme and other extreme weather events, suggesting that people living in these regions may have more direct experiences of extreme weather and climate hazards and thus are more likely to recognize climate change as a local concern.

The present study indicated that Chinese medical students were lack of specific knowledge on atmospheric CO_2 concentrations. According to a cross-country study in 2016 (Shi et al., 2016), knowledge of the causal drivers of climate change was correlated with higher levels of concern about climate change because it clarifies linkages between specific activities and greenhouse gas levels. Thus, there is a clear need to better inform medical students about the mechanisms and drivers of climate change.

The responses of closed-ended questions suggested that students may recognize the direct impacts of climate change on health but were likely to ignore more indirect pathways. Specifically, the identification of respiratory disease was larger than in any previous studies (Polivka et al., 2012; Syal et al., 2011; Balbus et al., 2008). One possible reason is that air pollution in China has worsened in recent years, which has aroused widespread media attention and became one of the most important environmental crises now (Lü et al., 2015). And heat-related illness was identified to be a climate threat by the majority of respondents in our study, consistent with several previous studies (Balbus et al., 2008; Bedsworth, 2009; Sarfaty et al., 2014), while smaller percentages were reported by public health officers in Oregon (Vynne et al., 2009), public health nurses (Polivka et al., 2012), health science students in Ethiopia (Nigatu et al., 2014). The differential findings may be due to that different levels of heat exposure at different locality.

On the other hand, mental health impacts were the least frequently identified as climate change related health concern in our study, similar to local health department directors (Balbus et al., 2008) and public health officers in Oregon (Vynne et al., 2009), though a higher concern was shown by public health nurses (Polivka et al., 2012). This may reflect a general bias toward under-recognition of the substantial mental health disease burden or be part of the trend toward heightened awareness of direct climate-health effects observed among Chinese students. And even though undernutrition has been widely recognized as an important climate change related health impact, a relatively low proportion of respondents identified it as a significant concern in our study. As undernutrition is heavily mediated through human institutions, people may underestimate this indirect impact of climate change. However, undernutrition could be a more pressing concern in the future, as China's large population and low per-capita resources may bring more challenges related to food insecurity driven by climate change (Tong et al., 2016; Wei et al., 2009).

From the discrepancy between closed-ended and open-ended responses, we argued that people's unprompted responses to our open-ended questions are likely a reflection of their actual understanding of the effects of climate change on health than their responses to close-ended questions. Because the responses to close-ended questions may be subject to three kinds of bias as following. First, respondents' answers to close-ended questions may reflect prompted recall, but with

Table 3
Factors influencing perception on health impact, vulnerable group, responsibility and ability (N = 1360).

Influence factors	Perception on health impacts		Perception on vulnerable groups		Perception on responsibility and ability	
	OR	95%CI	OR	95%CI	OR	95%CI
Gender						
Male	1	–	1	–	1	–
Female	1.21	(0.94,1.56)	1.27	(0.98, 1.63)	1.16	(0.90, 1.48)
Major						
Clinical medicine	1	–	1	–	1	–
Preventive medicine	0.71	(0.54, 0.92)	1.09	(0.83, 1.42)	1.36[*]	(1.04, 1.78)
Nursing	0.69[*]	(0.51, 0.94)	0.59[**]	(0.44, 0.81)	0.83	(0.61, 1.12)
Location of hometown						
Central China	1	–	1	–	1	–
Eastern China	0.96	(0.71, 1.29)	1.05	(0.78, 1.41)	1.07	(0.79, 1.44)
Western China	0.90	(0.65, 1.24)	0.86	(0.76, 1.58)	1.03	(0.74, 1.42)
Northeastern China	1.16	(0.80, 1.69)	1.09	(0.62, 1.18)	0.97	(0.67, 1.39)
Per capital income of family						
< $150	1	–	1	–	1	–
$150–299	0.78	(0.52, 1.17)	0.98	(0.65, 1.47)	0.93	(0.61, 1.40)
$300–749	0.99	(0.68, 1.44)	1.08	(0.74, 1.58)	0.84	(0.57, 1.22)
$750–1499	1.07	(0.71, 1.61)-	1.05	(0.70, 1.58)	0.71	(0.47, 1.07)
≥ $1500	1.38	(0.84, 2.27)	1.05	(0.65, 1.71)	0.80	(0.49, 1.31)
Self-rated health status						
Very good	1	–	1	–	–	–
Good	0.68[**]	(0.51, 0.90)	0.85	(0.65, 1.12)	1	–
Medium	0.55[**]	(0.38, 0.80)	0.68[*]	(0.47, 0.98)	0.87	(0.66, 1.15)
Poor	0.78	(0.29, 2.10)	0.75	(0.29, 1.95)	0.60[**]	(0.42, 0.87)
					0.21[**]	(0.07, 0.61)

* p-value < 0.05.
** p-value < 0.01.

open-ended question, the information was not available to them in an unaided memory search. Second, respondents who have relatively firm beliefs about the reality/unreality of climate change may tend to accept/deny all answers, which is harder for them to do with open-ended questions. Third, respondents who do not hold firm opinions on the reality and harmfulness of climate change may have an easier time inferring the "right" answers (the answers they think the investigators want to hear) and providing those answers in response to close-ended questions (Maibach et al., 2015). Fewer concerns were articulated overall in open-ended responses than in questions with closed-ended

prompts, suggesting that students may recognize the myriad ways in which climate change can affect health but be less confident of which relationships to climate change as particularly significant. Therefore, education efforts in information dissemination are needed and additional emphasis needs to be placed on indirect causal pathways through which climate change can affect our health.

4.2. Preparedness

Medical students in our study strongly endorsed their role in

Table 4
Medical students' perceptions on information sources and resources (N = 1387).

	Percentage (%)				χ^2	p-value
	Total	Clinical medicine	Preventive medicine	Nursing		
Information sources						
Electronic mass media (TV and radio)	70.1	66.6	73.0	73.2	6.9	0.03
Internet	94.5	94.3	94.9	94.6	0.2	0.91
University teacher	50.1	45.5	58.1	48.6	16.9	< 0.01
Newspapers/magazines	36.6	35.7	37.9	36.7	0.5	0.76
Friends/neighbors	34.8	37.6	28.4	37.7	11.2	< 0.01
Trustful information sources						
Scientists	59.0	60.2	62.1	52.1	8.3	0.02
University/College teachers	33.2	28.4	44.0	28.1	32.7	< 0.01
Community health professionals	21.8	22.8	18.6	24.0	3.8	0.15
Departments of Public Health	74.0	69.7	81.6	72.5	19.5	< 0.01
Medical communities/associations	43.2	45.5	39.5	43.5	3.8	0.15
Environment Protection Agencies	73.3	70.3	77.4	73.8	6.7	0.04
Bureau of Meteorology	76.4	71.7	79.8	81.2	14.4	< 0.01
Non-governmental Organizations	11.9	14.0	11.2	8.6	6.1	0.05
Others	1.5	1.7	1.2	1.6	0.5	0.77
Important resource needs						
Technical/analytical resources to assess health impacts	79.7	77.6	84.9	76.7	10.6	< 0.01
Dedicated funding for climate activities	69.3	65.8	74.7	69.0	9.4	< 0.01
Staff with expertise in climate sciences	83.1	80.3	87.9	82.1	10.9	< 0.01
Technical/analytical resources to assess vulnerability	58.0	55.4	61.9	58.1	4.4	0.11
Better coordination with state agencies	65.1	64.4	70.5	59.1	10.5	< 0.01
Better coordination with local agencies	59.1	56.2	65.1	56.9	9.3	< 0.01
Others	1.7	1.2	2.1	2.2	1.7	0.43

Table 5
Medical students' perceptions on education and training needs (N = 1387).

	Percentage(%)				χ^2	*p-value*
	Total	Clinical medicine	Preventive medicine	Nursing		
Integrated climate change into medical education systems						
Agree	79.8	71.7	89.1	83.7	51.9	< 0.01
Disagree	20.2	28.3	10.9	16.3		
Training needs						
Climate change-related clinical knowledge and skills	71.0	63.8	78.8	75.1	31.5	< 0.01
Extended clinical practice	45.6	43.0	47.7	47.9	3.2	0.21
Emergency care	59.4	56.7	59.8	64.5	5.4	0.67
Knowledge of population health	61.6	52.5	75.6	61.0	58.2	< 0.01
Knowledge of traditional Chinese medicine	15.9	14.8	15.3	19.2	3.2	0.20
Legal and ethical frameworks	24.8	24.5	25.3	24.6	0.1	0.95
Context in rural and remote practice	28.0	24.4	30.0	32.6	8.3	0.02
Local geographical and climatic knowledge	46.2	39.6	55.6	47.0	26.6	< 0.01
Contingency planning and management for extreme weather events	56.3	46.0	67.4	62.3	54.3	< 0.01
Others	1.2	1.2	1.6	0.6	1.5	0.48
Preferred training way						
Offer a new independent course	28.7	25.5	27.2	37.4	20.9	< 0.01
Integrate climate change into existing medical course	32.2	30.3	35.1	31.9		
Offer specific practical training	31.4	25.9	42.6	27.5		
Others	0.9	0.9	0.7	1.3		

responding to climate change and its health impacts. This high sense of professional responsibility implies favorable conditions for engaging them in climate and health education, advocacy campaigns or even broader environmental health issues. However, a large proportion of students did not believe that themselves or the health sector had made adequate preparations to climate change. In fact, many public health officers in the USA also claimed their departments having insufficient knowledge, expertise and capacity (Balbus et al., 2008; Polivka et al., 2012; Vynne et al., 2009) and this situation are thought to be even worse in China. The gap between responsibility and ability should raise the concern about what capabilities are necessary for health professionals in the context of climate change and what institutional settings can make health sectors more resilient to climate change.

4.3. Medical education

The need for additional resources to address climate change was acknowledged by many medical students. Experts on climate change and health was identified as the most pressing need in our study, while lack of funding was the greatest concern among public health officers in the USA (Vynne et al., 2009; Balbus et al., 2008; Bedsworth, 2009). This suggests different barriers to implementing climate adaptation measures in different countries. To better cope with climate change, China should increase the cultivation and reserve of interdisciplinary talents for climate change and health.

Internet and other electronic mass media (TV and radio) were demonstrated as the most popular source of information on climate change among our respondents, similar to previous studies in Ethiopia (Nigatu et al., 2014) and in Malaysia (Rahman et al., 2014), while nine tenth of local public health officers in California chose scientists as their information source (Bedsworth, 2009). Our finding highlights the critical role of mass media in covering climate change and in helping guide climate change-related education and communication efforts. Further studies of the role of internet and social media may facilitate the development of strategies to increase students' knowledge of climate change impacts. Yet, this finding also suggests there may be an informational vacuum in medical student training, and there is a need for explicit treatment of the topic in the Chinese medical curriculum.

Based on our results, Chinese medical students still need a lot of improvements in their perception and preparedness and we argue to address this issue through educational efforts. In response to climate change, a qualified health professional should be able to obtain,

understand, integrate and employ climate change and health-related ecological effects information and improve health services. This kind of ability was defined by Bell (2010) as "eco-medical literacy". Developing eco-medical literacy and capacity building among medical students can help facilitate preparedness. Maxwell and Blashki (2016) argued that curriculum integration is the most straightforward and efficient approach with this aim, and this approach was also widely suggested by our respondents. Relevant courses on the climate change/human health interface could be included in the curriculum of Chinese universities, and expanded medical curriculum should be first carried out among preventive medicine students given their lower perception of climate change and its health impacts. These efforts can leverage activities to promote climate and health education already under way through the Global Consortium on Climate and Health Education, an initiative funded by The Rockefeller Foundation, which aims to unite schools of medicine, nursing and public health in sharing best practices to build curricula and core training (Friedrich, 2017). Chinese medical universities may join this consortium and follow-up studies may comprehensively reveal what competences are needed and what educational modes are appropriate to achieve satisfactory knowledge of medical students at graduation.

Some limitations to this study should be considered. First, despite our sampling frame was designed to gather opinions from a range of region in China, not all results could be generalized to the overall cohort of Chinese medical students. Because the students engaged in this study were from top universities in China, there may be lower perception in other universities. Second, as data on personal extreme weather experience were not collected, we cannot explore it as a potential driver for regional difference of perceptions. Third, this is an opinion survey and there are no gold standards for most questions. However, we think it is still valuable to understand the current students' perceptions of climate change, both in terms of overall perceptions of health risks and vulnerability, and in providing meaningful information of perception and information deficits.

In conclusion, this survey found that most medical students in China were aware of climate change and its health impacts. Although medical students embraced their role in responding to climate change, they did not feel that themselves or the health sector are adequately prepared. The high awareness and level of concern in general can serve as a strong foundation for developing additional training in medical education, and particularly efforts should be considered to integrate climate change into established curricula.

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Ethical approval

This work was approved by the medical ethics committee of School of Public Health, Sun Yat-sen University [ethical approval number 2016030]. Written informed consent was obtained from study participants.

Conflicts of interests

The authors declare no conflicts of interests.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envres.2018.10.006.

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